Suite 2101, 4464 Markham St.
Victoria, BC, V8Z 7X8, Canada
Phone: +1.250.483.3300
Fax: +1.250.483.3301
www.jasco.com

Preliminary Acoustic Level Measurements of Airgun Sources from GX Technology Corporation's 2006 Arctic Span Seismic Survey

By Melanie Austin, Marjo Laurinolli and David Hannay
JASCO Research Ltd., Victoria, BC
August 25, 2006

Overview

JASCO Research Ltd prepared estimates of airgun array sound level radii for use by GX Technology for their 2006 Artic Span seismic program in the Beaufort and Chukchi Seas. These included range estimates for rms noise levels to 180 dB re µPa and 190 dB re µPa. JASCO has subsequently carried out *in situ* measurements to obtain high-resolution calibrated recordings of the actual underwater noise signals from the airgun array on August 20-21, 2006. This report gives preliminary results of the analyses of the airgun recordings and provides endfire and broadside ranges to the 190–120 dB rms levels.

Introduction

GX Technology is conducting a seismic airgun survey program in the Beaufort Sea and Chucki Sea in 2006. The primary survey vessel for this program is the MV Discoverer, operated by SOPGC, which tows a 3320 in^3 airgun array while surveying. The airgun array layout is shown in Figure 1.

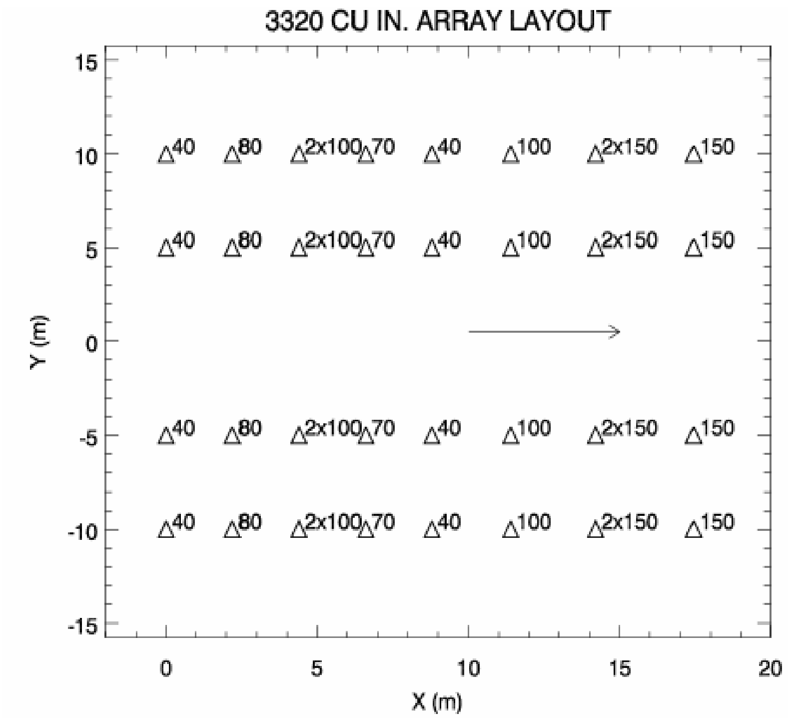

Figure 1 Plan view layout of GXTs 3320 cu in airgun array.

On August 20–21, 2006, JASCO Research Ltd carried out underwater OBH measurements to provide *in situ* estimates of noise threshold level radii for the Discoverer's airgun array and to compare with predictions from pre-season noise modeling. This preliminary report is intended to provide initial estimates of ranges to the 190–120 dB rms levels for GX Technology's 2006 Arctic Span seismic survey program.

Field Recording Operations

JASCO Research performed acoustic measurements using two calibrated On-Bottom Hydrophone (OBH) recording systems. The OBH systems were deployed from the 120-foot support vessel MV Octopus. Ideally the recordings would have been carried out at the same location as used in the pre-season modeling, 71°15.1N 163°11.7W, but the occurrence of other seismic programs in the area prevented the survey vessel from operating at that location. The location, 69°56N 167°03W, which has similar bathymetry, was chosen as an alternate measurement location.

The OBH systems were deployed from the Octopus, which departed the deployment area to avoid noise contamination of the recordings while Discoverer performed airgun array shooting along a planned noise level verification survey track. Digital acoustic recordings of approximately 16 hours of shooting data were obtained from each OBH as the Discoverer followed the survey lines. Octopus then returned to the survey area and recovered the OBHs. Figure 1 shows the measurement plan, indicating the position of the two OBH systems in relation to the survey vessel track.

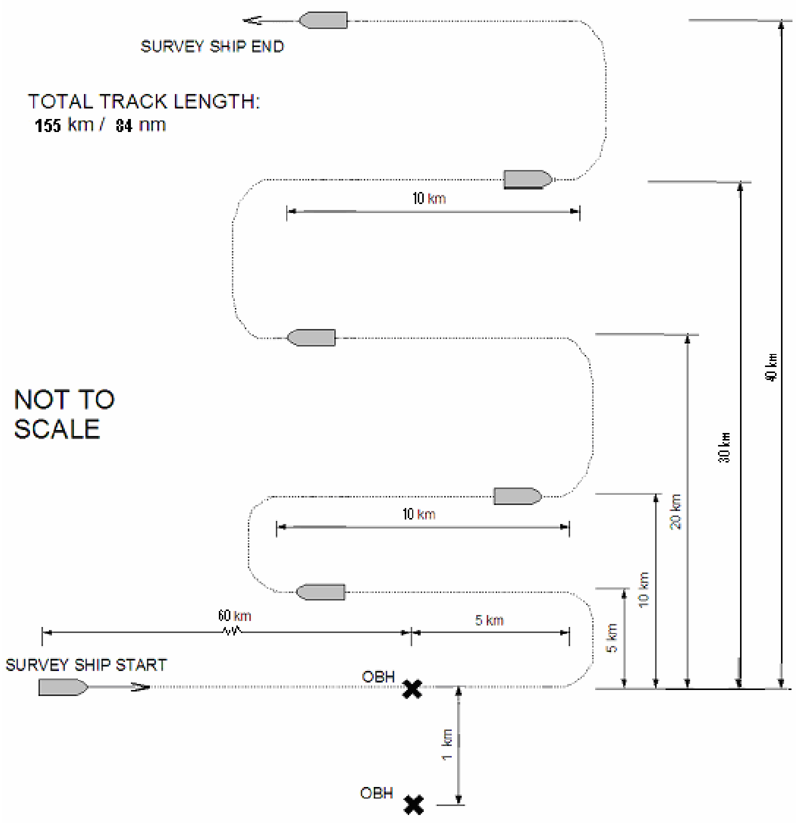

Figure 2 Survey vessel track lines relative to OBH positions during acoustic measurements.

Acoustic Recording Equipment

Two identical OBH systems were utilized. Both OBH's use two Reson calibrated reference hydrophones with different sensitivities: TC4043 (nominal sensitivity -201 dB re V/uPa), and TC4032 (nominal sensitivity -170 dB re V/uPa). The use of hydrophones with different sensitivities was done to capture the wide range of pressure variations experienced as the source moved from more than 60 km to less than 100 m range from the OBH. At the closest ranges the more sensitive hydrophone (TC4032) was saturated by the high pressure signals.   Digital recordings were obtained with calibrated Sound Devices model 722 24-bit audio hard-drive recorders set to sampling rate 32 kHz. Post-recording, two copies of all data were backed up to separate external hard drives.

Figure 3 OBH system being recovered by the Octopus.

Data Analysis

Preliminary data analysis were carried out to determine peak, rms and SEL sound pressure levels versus range from the airgun array sources. The data processing steps carried out were as follows:

1.) Delineate each pulse to determine start times.
2.) Apply hydrophone sensitivity and digital conversion gain to digital recording units to convert to microPascals (μPa).
3.) Determine the maximum sound pressure level for each pulse in dB//μPa.
4.) Compute cumulative square pressure functions through each pulse's duration.
5.) Determine times at which 5% and 95% of the cumulative square pressure for each pulse was received.
6.) For each pulse, compute the rms level by dividing the cumulative square pressure between the 5% and 95% times by the number of samples in this period, and taking the square root.

Airgun shots were evident in some of the data files that did not correspond to the shot times when the Discoverer was firing its guns. These signals are attributed to third party seismic programs that were operating concurrently in the Chukchi Sea. This was most notable in the data files where the source receiver separation was large and thus the GX airgun signal levels were comparable to the external airgun signals also received from long ranges. Care was taken in the data analysis to ensure that these airgun signals did not interfere with the present calculations.

Discoverer followed a slightly modified survey track as shown in Figure 2. The OBH located directly below the survey track, and indicated with a red star, is referred to as OBH A, the other as OBH B and is also indicated with a red star in the figure. Discoverer utilized its array in full capacity throughout the entire survey and there were no dropped guns or missed shots reported.

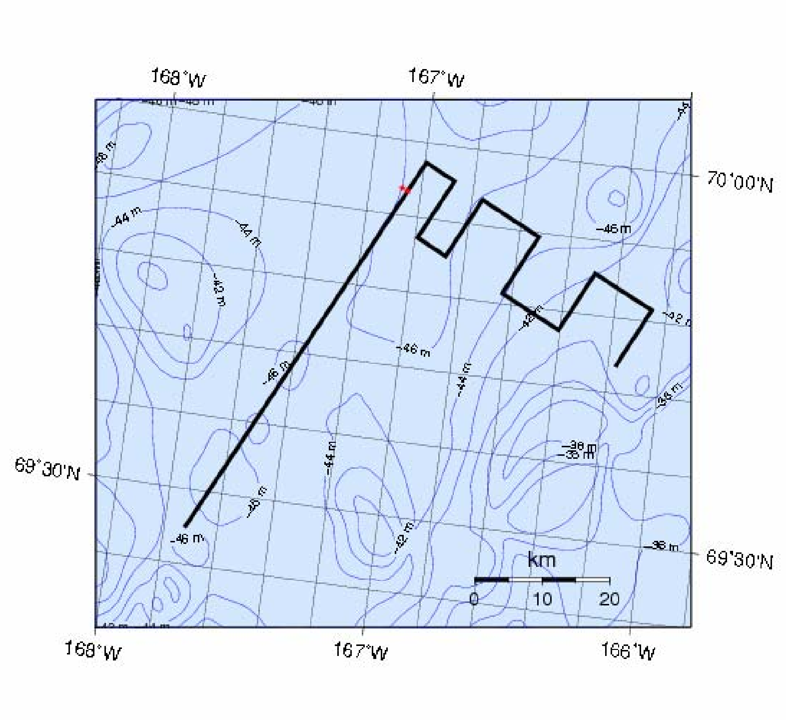

Figure 4 Discoverer track during shooting measurements. Positions of the two OBH systems are indicated by the red symbols.

Results

Ranges from the center of the airgun array to the OBH recording positions were computed for the times corresponding to each shot using the navigation logs supplied by the Discoverer upon completion of the survey. The data presented in this section are from both OBH systems and it is noted that excellent agreement, less than 1 dB and also less than shot-to-shot level variations, was observed in the pressure measurements made by the two systems. At ranges greater than 20km the data from the more sensitive hydrophone were used, while at shorter ranges the data from the less sensitive hydrophone were used. This approach prevent including data that may have been clipped as the signal levels increased due to airgun proximity to the OBH's. The data from the more sensitive hydrophones were clipped at ranges closer than approximately 4.5 km.

Sample pressure waveforms are presented in Figures 5 and 6 of individual airgun pulses received at ranges of 250m and 51km respectively. Also shown are the spectral distributions for the respective pulses.

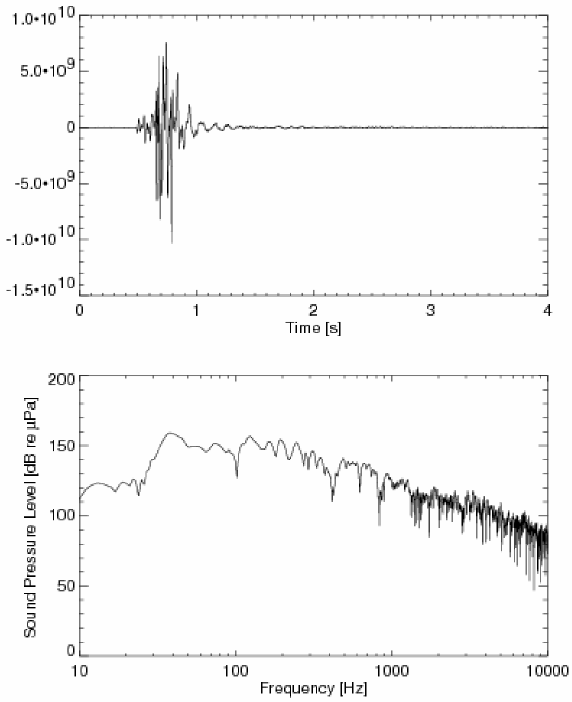

Figure 5 Pressure waveform (top) and spectral distribution (bottom) for a single airgun pulse received at 250m range.

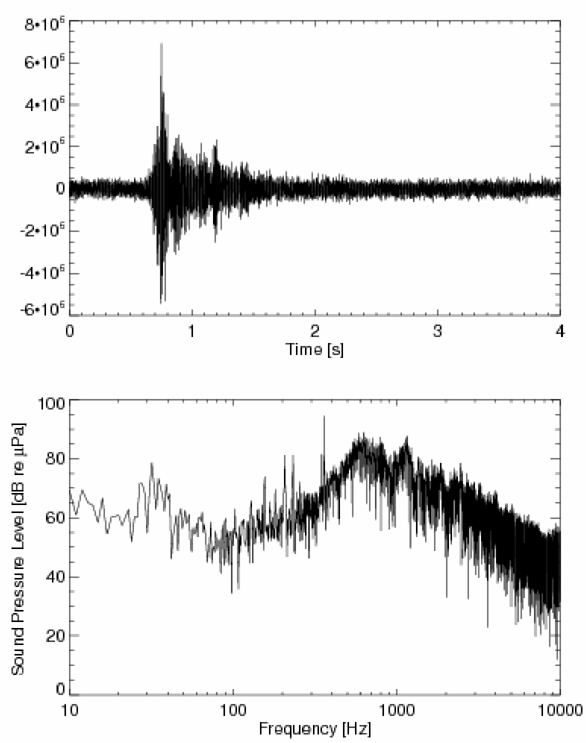

Figure 6 Pressure waveform (top) and spectral distribution (bottom) for a single airgun pulse received at 51km range.

The peak and rms sound pressure levels (SPL) and sound exposure level (SEL) for each shot were computed for each OBH system and are plotted against the corresponding source-receiver ranges. Estimates for 190-120 dB ranges, in 10 dB steps, based on these endfire and broadside levels were then established. The data were separated into results received from the array endfire aspect and those from the broadside aspect and are plotted in Figures 7 and 8 respectively.

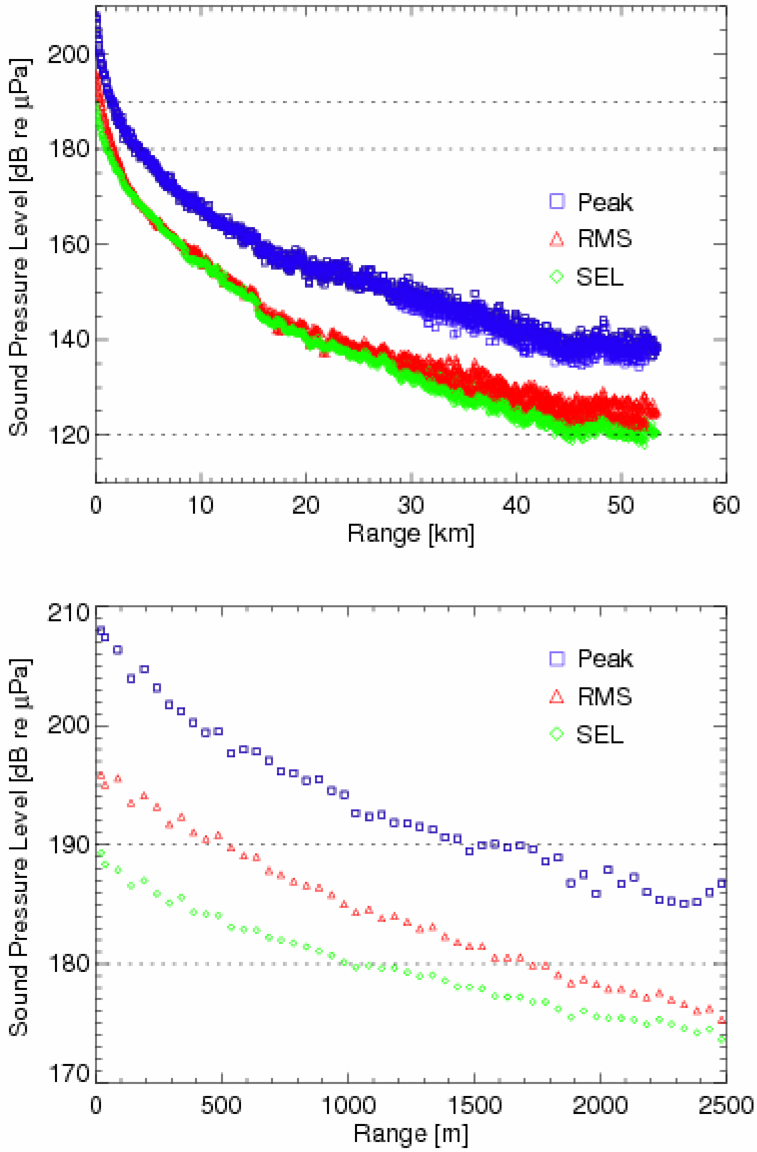

Figure 7 Peak, rms, and SEL levels for airgun pulses received from array forward endfire, presented at two extent scales.

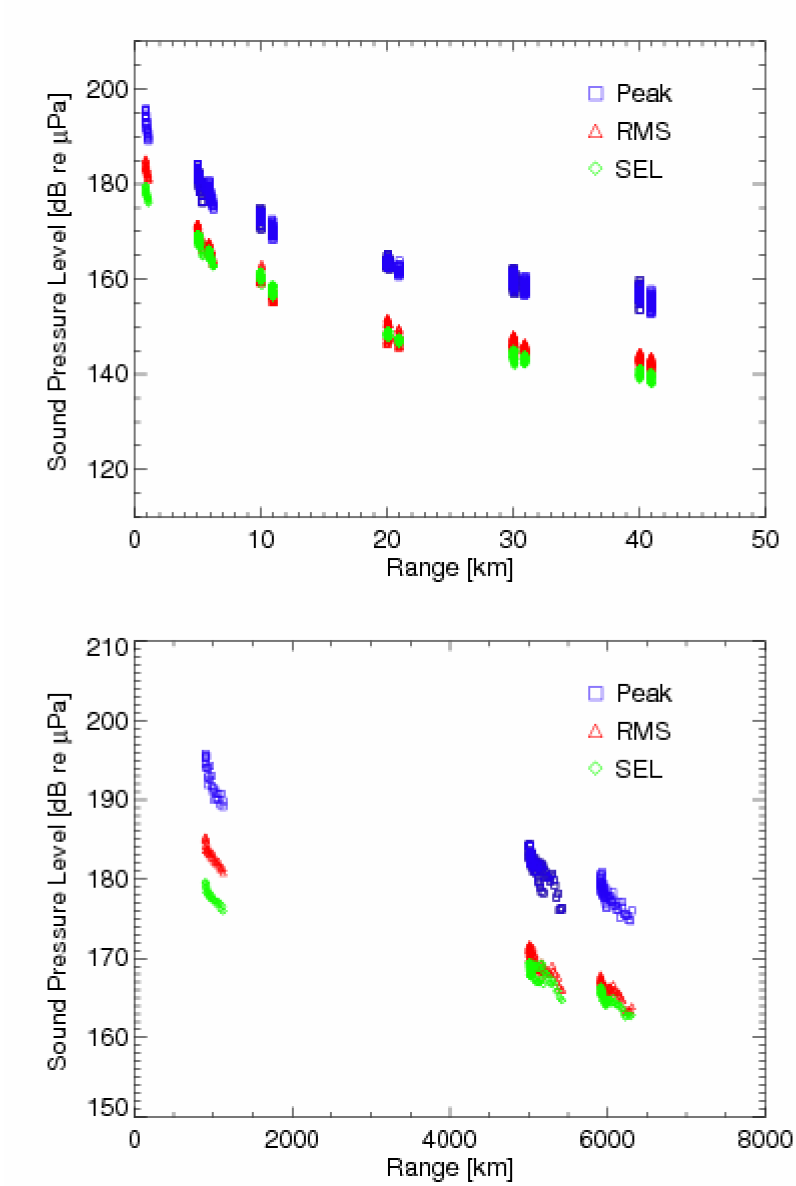

Figure 8 Peak, rms, and SEL levels for airgun pulses received from array broadside, presented at two extent scales.

It is noted that at a given range the broadside levels in Figure 8 are approximately 5 dB re µPa greater than the corresponding endfire levels in Figure 7. This is due to the array directivity.

Threshold level ranges

Ranges from the airgun array to the 190–120 dB rms sound pressure level (SPL) thresholds were determined from acoustic data obtained on the OBH systems. The transmission loss equation in the form $RL = SL - n \log R + \alpha R$ was fit to the sparse broadside data; in the equation RL is the received level, SL is the source level, n is a transmission loss coefficient, α is an attenuation loss coefficient and R is the range from the source to the receiver. Different values for the coefficients were used to fit the 'close range' data ($R < 20$km) and the 'far range' data ($R \geq 20$km) separately and are presented in the following table. For the ‘close range’ data the curve was fit to the highest received rms values as this is the most precautionary approach for sound levels that are most biologically significant in terms of having the potential to cause injury to marine mammals. A least-squares fit to the ‘far range’ data was considered to be more acceptable for providing the radii to sound levels of 120 dB, to which there are only potential behavioral reactions of the animals at that level.

Table 1 Coefficients used to fit the tranmission loss equation to the data at different ranges.

	R < 20 km	**R ≥ 20 km**
n	17.4	13.5
α	0.00057	0.00023
SL	238.1	214.6

The resulting curves are shown in Figure 9 and Figure 10 and the equations for the fits are indicated on the plots.

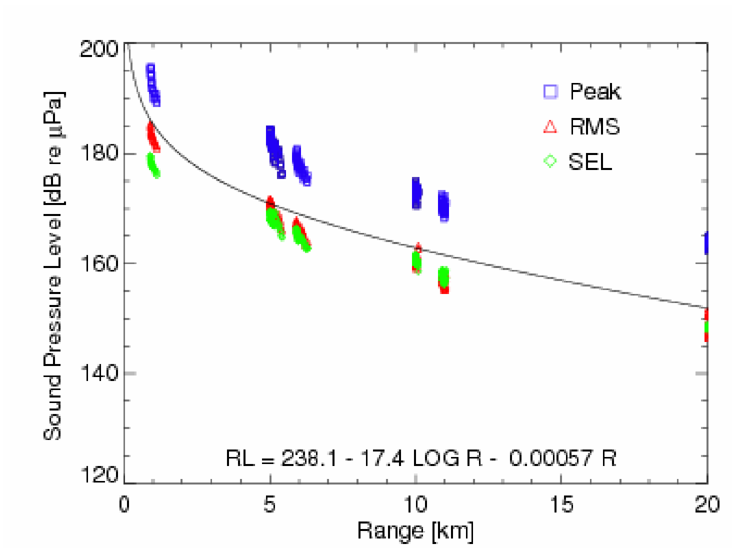

Figure 9 Transmission loss curve fit to the broadside rms levels received at less than 20km range from the source, for radii determination

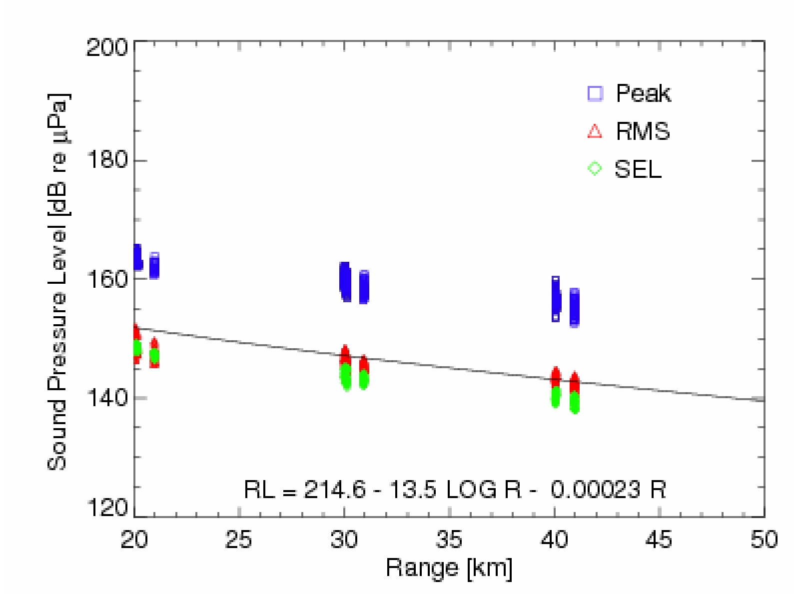

Figure 10 Transmission loss curve fit to the broadside rms levels received at greater than 20km range from the source, levels for radii determination.

The resulting rms radii are tabulated in Table 1 and Table 2. The radii for rms levels between 140 and 190 dB were taken using the curve in Figure 9 and the radii for levels between 120 and 150 dB were determined using the curve in Figure 10. The broadside ranges are larger than the endfire ranges, however the angular zone ensonified by the broadside zone is narrow and is therefore small compared to area of the endfire zone. Note that the 120 dB radii were determined by extrapolating the trend in the rms data received at ranges greater than 20km and thus should be considered as an approximation. Sound level radii from the pre-season acoustic modeling are also shown for comparison; it is noted that the model results are for a receiver at 10m depth but the measurements were received on the seafloor.

SPL	Forward Endfire Range (m)	Flat-weighted Range from Pre-season Estimate (m) [1]
120 dB rms	55000	46100
130 dB rms	37700	33300
140 dB rms	23500	20800
150 dB rms	14500	10400
160 dB rms	8080	5600
170 dB rms	3740	3200
180 dB rms	1730	1500
190 dB rms	537	250

Table 1: Sound threshold level radii from 190 dB to 120 dB, in 10 dB increments, for airgun array endfire.

SPL	Broadside Range (m)
120 dB rms	113000
130 dB rms	79000
140 dB rms	48600
150 dB rms	23800
160 dB rms	12400
170 dB rms	5450

180 dB rms	1900
190 dB rms	558

Table 2: Sound threshold level radii from 190 dB to 120 dB, in 10 dB increments, for array broadside.

References

[1] Zykov, M., Racca, R.., MacGillivray, A., Characterization of Noise Emissions from GX Technology Corporations' 2006 Seismic Survey in Alaskan Chukchi Sea and Canadian Beaufort Sea. JASCO Research Ltd. Report August 23, 2006.